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Deflation processes and their role in desertification of the southern Pre-Balkhash deserts

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Abstract Deflation processes are important in arid environments such as deserts. The deserts of Kazakhstan mostly cover lowlands and extend from the eastern coast of the Caspian Sea to the piedmonts of the Tien-Shan Mountain. Desert areas are also major source areas of dust/sand storm activities. We considered deflation processes in the southern Pre-Balkhash deserts. In Kazakhstan, desertification processes due to wind erosion in the form of dust/sand storms were observed in semi-desert and desert landscapes. During analysis of numerous long-term meteorological data and cartographic materials, we revealed the sand movement directions which allow prediction of future potential sand movement patterns or processes in southern Pre-Balkhash deserts. The Taukum, Moiynkum deserts, Ili river deltas and valleys, and southern coastal of Lake Balkhash are most prone to dust/sand storms. The most frequent storms were observed in the Bakanas weather station (Ile river valley). Sand/dust transport occurs mainly in the east, south-east north-east direction in the southern Pre-Balkhash deserts. The high amount of sand transportation was observed at the Kuigan weather station; low amounts were encountered at the Naimansuiek weather station. The amount of airborne sand/dust varies in accordance with the general and local meteorological features, the complexity of relief forms, soil conditions and properties, lithology, and various contributions of the human activities. Thus, our study on deflation processes in the southern Pre-Balkhash deserts has great importance towards aiding in the prediction and monitoring of dust/sand storms and movement patterns.

Keywords Deflation processes · Desertification · Dust and sand storms · Kazakhstan · Soil degradation

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Introduction

Destruction of soil surfaces as a result of wind impact is most commonly referred to as deflation process. This process includes removal, transportation, and re-deposition of soil mass. Kazakhstan has differing soil and climatic conditions, topography, and geology; deflation processes are very common (Dzhanpeisov 1977; Uteshev and Semenov 1967; Gael and Smirnova 1963; Belgibayev 1993).

Deflation processes in deserts and dust deposits occur due to physical–geographical and climatic conditions of the region (Yang and Scuderi 2010; Uteshev and Semenov 1967). The process is especially intensive in areas of Aral, Caspian Seas; man-made Aralkum and southern Pre-Balkhash deserts as well Karakum and Kyzylkum deserts in Central Asia are the main source areas of deflation process as dust/sand storms, which affect the entire region (Orlovsky et al. 2004, 2005). The vast expanse of deserts across Central Asia experience dust/sand storms of different frequencies, intensities, and durations. Due to the great variety and abundance of loose material available for transportation, the frequency of dust/sand events varies over a wide range of 5–146 days of dust/sand storms per year (Dedova et al. 2006; Galaeva and Idrysova 2007; Orlovsky et al. 2005). Desert areas are more often the principal source of dust storm development (Squires 2001; Yang and Scuderi 2010; Moutaz et al. 2012). Almost all major sources of dust/sand storms are located over topographical lows or on lands adjacent to strong topographical highs, where fluvial action is evident by the presence of ephemeral rivers and streams,

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alluvial fans, playas, and saline lakes (Prospero et al. 2002). The long-term and seasonal variability of dust/sand storms is affected by various parameters including climate, geomorphology, and human activities (Yang 2001; Yang and Scuderi 2010; Yang et al. 2006). Kazakhstan and Central Asia is an extremely large region of varied geography and climates, thus dust/sand storm activities are highly variable at annual and inter-annual scales. In general, the Central Asian and Kazakhstan dust/sand outbreaks are common for the spring and summer seasons, though they are not an exception for the autumn and winter months (Indoitu et al. 2012). Central Asian and Kazakhstan deserts are characterized by strong winds, scarcity of vegetation cover, continental and Mediterranean climate with long dry summers, lack of soil moisture, relatively low air moisture, and frequent repletion of soil and atmospheric droughts (Indoitu et al. 2012). Deserts are dry fragile areas with little or no vegetation. Therefore, winds can remove sand-, silt-, and clay-sized particles from the surface and transport them during dust and sand storms over great distances (Al-Dousari et al. 2012). The main persistent sources of dust/sand storms of Central Asia and Kazakhstan are located in the large "dust belt" that extends from west to east over the southern deserts, north of Caspian Sea deserts, Aral Sea region (Kyzylkum, Aralkum deserts), and southern Balkhash deserts. The high frequency of dust/sand storms occurs mainly in the sandy deserts, and other types of deserts where sensitive ecosystems have suffered substantially from human impact (Orlovsky and Orlovsky 2001; O'Hara et al. 2000; Indoitu et al. 2012).

Sand and dust storms are both a symptom and cause of desertification. Desertification is defined as land degradation in arid, semiarid, and dry sub-humid areas resulting from various factors including climatic variations and human activities (UNEP 1992; Elsayed 2012). The process is one of the most dangerous ecological and socioeconomic issues facing the global community on the threshold of the twenty-first century, which occurs primarily in the form of encroachment on arable land, but rangelands are also under threat. Asia is a vast region, home to more than half of the world's population, and one of the world's most adversely affected regions by desertification. China is one of the countries severely plagued by desertification. The effects of desertification in China are mainly in the form of encroachment on arable land, destruction of forest ecosystems, and worsening sandstorms that blow across large areas of the northern and western regions (Yang 2010; Yang et al. 2007).

Desertification due to wind erosion (deflation process) has touched the semi-desert and desert landscapes of Central Asia and Kazakhstan (Parakshina et al. 2010; Babaev 1999). The problem of desertification in Central Asia is more serious; 75 % of the territory in Kazakhstan, 60 % of Uzbekistan, and 66 % of the territory in Turkmenistan are prone to anthropogenic desertification (Alibekov and Alibekov 2008).

The development of desert land resources in Kazakhstan has intensified during last 10 years. Unsustainable land practices and irrational use of natural resources and environment pollution lead to land degradation and desertification in almost every Kazakhstan region. The problem of soil degradation and desertification is the most serious problem of land agriculture development in Kazakhstan (Almaganbetov and Grigoruk 2008). The processes of soil degradation and desertification have occurred due to anthropogenic activity and level change of the Aral Sea and Balkhash Lake in Kazakhstan. Regulation of the level of the Syrdarya and Ili rivers flow led to the reduction of groundwater level, increasing their mineralization, soil salinization, and drying of pond leading to promotion of deflation processes (Skotselias 1995). At present, most territories of Kazakhstan have high risk of desertification and 179.9 million hectares from 272.5 million hectares (about 75 %) have succumbed to desertification (CSD 2002). Many pasture areas (about 14 %) have reached an extreme degree of degradation and were lost due to overgrazing by livestock. Processes of land/soil degradation and desertification are especially intensive in areas of Aral, Caspian seas, and southern Pre-Balkhash deserts (Iskakov and Medeu 2006). The degradation is accompanied by intensive soil salinization that leads to the growth of solonchak desert areas in drainless basins and irrigated lands (Orlova and Saparov 2009). Soil salinization, land/soil degradation, and plant change toward more xerophyte types are signs of desertification (Kovda 2008; Hamid et al. 2013).

In the 1970s, after the creation of the Kapshagai water reservoir and intensive use of water from Ili, Karatal, and Lepsi rivers, it led to a decrease in the water level of Lake Balkhash where the mirror pond reduced up to 4,700 km^2. As a result, a considerable portion of coastal land area of Lake Balkhash has undergone soil salinization and degradation. Water resources of the rivers are mainly used for irrigation, and also for water supply and electric energy production. Reduction and regulation of Ili and Karatal rivers flow led to the drying of many lakes, including salty lakes in deltas of these rivers (Skotselias 1995; Belgibayev 2001; Kudekov 2002). As a consequence, the new sources of soil deflation and sources of dust/sand storms have appeared in the southern Pre-Balkhash deserts that lead to high concentration of salts in the atmospheric flows. These salts provoke deterioration of pastures, reduction of biodiversity, salinization, and desertification of soils.

From this review, it is clear that investigations of soil deflation, desertification, and land/soil degradation are important and required.

Study area

The research was conducted in the southern Pre-Balkhash deserts. Specific features of general lithological–edaphic conditions in the formation of Central Asian and Kazakhstan deserts are classified into six groups as follows: sandy,

sandy-gravel and gravel, crushed stone-gypsum, loess, clay, and solonchak (Babaev 1999). The southern Pre-Balkhash deserts belong to sandy deserts. The sandy deserts are located in southeast Kazakhstan, within vast (by size of about 70,000 km^2) shallow southern Balkhash Depression. This depression is bordered by Shu-Ili Mountains in the west, by Balkhash Lake in the north, and by Arganty, Arharly, Saikan mountains, and northeastern spurs of Zhetysu (Dzhungar) Alatau in the east (Dzhanalieva et al. 1998; Skotselias 1995). Taukum and Moiynkum deserts are stretched along the left bank of Ili river; Saryesikatyrau, Bestas, Irizhar, and Zhamankum deserts are located between Ili and Karatal rivers. Zhalkum sands are situated between Karatal and Aksu rivers (Fig. 1). Erosion processes are most intensive in piedmont areas composed mainly of poorly cemented sandstones, loess loams, and similar ground subject to easy scouring and weathering. After the demise of the ancient river system, the alluvial plains were gradually subject to deflation and aeolian dissection. Therefore, in Central Asia, most widespread are sandy deserts that were largely formed in areas of development of ancient or modern alluvial or lacustrine–marine loose deposits (Babaev 1999).

The territory of Balkhash Lake basin is characterized by great diversity and complexity of geological structure. The Balkhash Depression is formed in the Neogene period. The Paleogene rocky deposits are found mainly in the periphery (Abdullin 1994).

The climate of deserts in Kazakhstan, Central Asia, and elsewhere in the world are characterized by high air temperatures and a long dry period during the summer. Climate of the southern Pre-Balkhash is continental, arid, characterized by large daily and annual variations of air temperature, and high levels of solar radiation. Mean air temperature during the coldest month (January) is −16 °C in the northern part and −5 °C in the southern part of the plain territory. Mean air temperature during the hottest month (July) is about 20–25 °C. Distribution of precipitation over the region is very variable: about 150 mm falls on the north, northwest (coast of

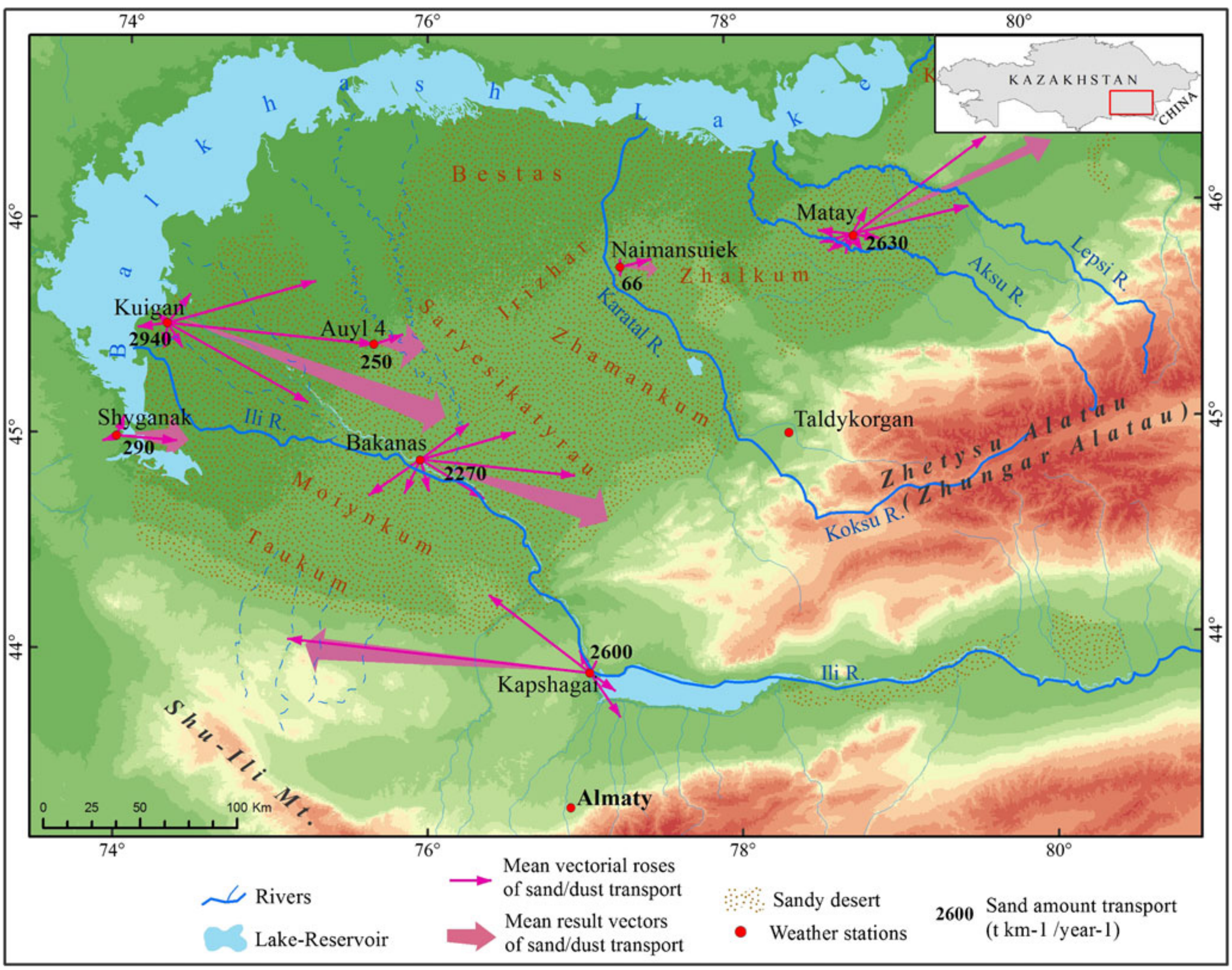

Fig. 1 Sand/dust movement direction in the southern Pre-Balkhash deserts

Balkhash Lake), and 200–300 mm in the southeast. Precipitations during the warm time of the year on the plain are almost completely spent through evaporation. The biggest monthly amount of precipitations falls during spring months (April–May) and the smallest during February and August–September (Akhmedsafin et al. 1980).

Materials and methods

Soils in deserts are very thin; humus content in them is meager (Faizov et al. 2006). The main soil types in the region are sandy desert, gray-brown, takyr-like, takyrs, and solonchaks. The sandy desert soils dominate in the southern Pre-Balkhash deserts. They are stretched in the latitude direction from the western bank of the Balkhash Lake up to Alakol Lake in the east (Faizov 1983). The foothill plains of Arganty Mountain are covered by gray-brown soils, while foothill plains of the Shu-Ili Mountains have predominantly light sierozems with fine structure. Floodplain meadow soils are typical for major near-river plains and deltas, such as Ili river. Modern floodplain terraces of rivers in the southern Pre-Balkhash deserts have alluvial-meadow soils and shallow groundwater. The takyr-like soils are distributed in most areas of Bakanas and Akdala ancient dry delta plains, along the left bank of Karatal river and northeast outskirts of Zhusandala. The takyr-like soils have mostly fine structure (Asanbayev and Faizov 2007). Takyrs are very common in the southern Pre-Balkhash deserts, but they cover small area and often are buried under sands (Faizov et al. 2006). Solonchaks are common along the coastal stripe of the Balkhash Lake. The largest solonchaks are found in western and eastern coast of the Balkhash Lake, as well as in the delta of Ili river, where all types of solonchaks are observed. The desert solonchaks are the main source for salt atmospheric aerosols (Orlova and Seifullina 2006). Surface layer of solonchak is covered by soluble salts (Borovsky 1978, 1982). The sparse vegetation of the region is presented by Ephedra, sagebrushes, and various shrubs (Kudekov 2002; Ivashenko 2005).

Meteorological features (temperature and dryness) of the southern Pre-Balkhash deserts and its landscape with sparse vegetation are prone to dust/sand storms because winds blow soil particles from the ground surface very easily. Dust/sand/salt storms often happen simultaneously with hot dry winds in the region (Semenov 2011; Fediushina 1972a, b). They play an important role in the removal of salt from solonchak (Orlova 1983; Jilili Abuduwaili et al. 2008).

For the analyses about dust/sand storms and to show the dynamics of dust/sand storms, the long-term observations data of dust/sand storms in the region from four meteorological stations for the period between 1971 and 2010 were used. We have analyzed as well the seasonal frequency of dust/sand storms in the desert zone of Kazakhstan according to average number of days with dust/sand storms in different months for the period of 1966–2003 from seven weather stations.

For the purpose of analyses and calculation of sand/dust transportation in the southern Pre-Balkhash deserts region, data of wind speed, wind direction, and average size of sand particles in the period of 1966–1986 from seven weather stations (Matay, Naimansuiek, Auyl 4, Kuigan, Shyganak, Bakanas, and Kapshagai) were used to conduct quantitative assessment and determine dominant direction of sand movement during the deflation processes.

The sand/dust transportation in southeastern Pre-Balkhash deserts between Karatal, Aksu, and Lepsi rivers were investigated according to the data from Matay and Naimansuiek weather stations. Parameters of sand amount transport in the left bank of Ili river (Taukum and Moiynkum deserts) were done according to the data from Shyganak, Kurty, Kapshagai, and Bakanas weather stations. The western part of the Saryesikatyrau desert was characterized according to data from the Auyl 4 station, and eastern part of this desert by data from the Naimansuiek weather station. The transported sand masses at the surface, the probability and direction of sand movements, and dust particles transport were calculated using the model created by Semenov (1988). The received model allowed calculation of sand/dust transport by the wind in various Kazakhstan regions and estimation of objectively possible intensity of sand deflation.

The Semenov model allows one to calculate the amount of sand/dust which is transported through a distinct migration plain of 1 km in length by sand drift (between 10 and 30 m) and by dust transport (between 150 and 200 m). The model was applied to calculate the amount of sand carried by wind in the ground layer during sand/dust deflation. This study represents the first quantitative assessment of intensive of deflation process in the Pre-Balkhash desert region. The amount of sand/dust transported during the storm can be calculated using the following formula:

$$M = \Delta\tau_0 \cdot Q_{zl} + \sum_{i=1}^{n} Q_{zi} \cdot \Delta t + \Delta\tau_k \cdot Q_{zn} \qquad (1)$$

Where $\Delta\tau_0$ is the time interval from the moment of storm beginning to the first next hour of observation, Q_{zi} is the total amount of sand in a surface layer of the atmosphere in the ith hour of measurements, Q_{zl} is the total amount at an initial interval of time, and Q_{zn} at the final interval of time. Q_{zl} and Q_{zn} are calculated by wind speed in the first and the last standard measurements during a storm. Δt is the time interval between the standard meteorological observation equal to 3 h or 10,800 s, $\Delta\tau_k$ is the time interval between last standard hour when the storm was still observed, and its termination. In such a manner, sand amounts are calculated for all dust storms and ground sand transportation in the observations archive, and two information files are formed. Sand amounts in the

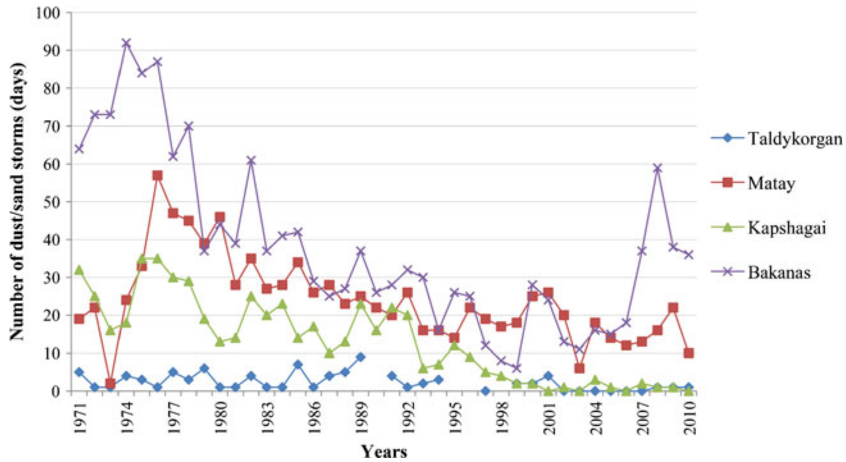

Fig. 2 Long-term dynamics of dust/sand storms in the southern Pre-Balkhash deserts

first file are considered to be scalar without taking into account a direction of transport. The second file contains vector characteristics of a wind–sand stream, i.e., amount of sand together with transport direction.

For calculation of transported sand/dust masses, vectorial dynamics was used. The vectorial roses display which masses of dust/sand is transported in the lower atmosphere by wind in which direction. The length of the vector arrow represents the amount of sand/dust transported (Fig. 1). This is known from changes in the shape of the newly formed barchans and other aeolian relief forms, which can change their direction of movement several times according to the prevailing strong wind vectors. However, the resultant (vector addition) gives an idea of the overall long-term sand/dust movement and transport integrated over time (Fig. 1). The resultant vector shows the final direction of the sand/dust transport.

On the basis of map–schemes (Fediushina 1972a, b; Semenov and Tulina 1978), we constructed the map of sand/dust movement direction in the southern Pre-Balkhash desert region (Fig. 1).

Results and discussions

Dust/sand storms

Dust/sand storms are common events in the arid and semiarid regions of Kazakhstan and Central Asia. They contribute to the spread of desertification and development of intensive deflation. For the continental Kazakhstan climate and according to observations of meteorological stations, the high wind speed regime and scarcity of vegetation cover, frequency of soil and atmospheric droughts, and dust/sand storms are typical almost all over the Republic (Semenov and Tulina 1978). However, the distribution of dust/sand storms is extremely heterogeneous in Kazakhstan and is characterized by large diversity. According to long-term meteorological data, we found areas which had undergone dust/sand storms more frequently. The dust/sand storms dynamics in the region are demonstrated on Fig. 2. There are large numbers of dust/sand storms in the Bakanas station because their takyr-like soils contain many silty sand sediment and clay particles. Additionally, the regions

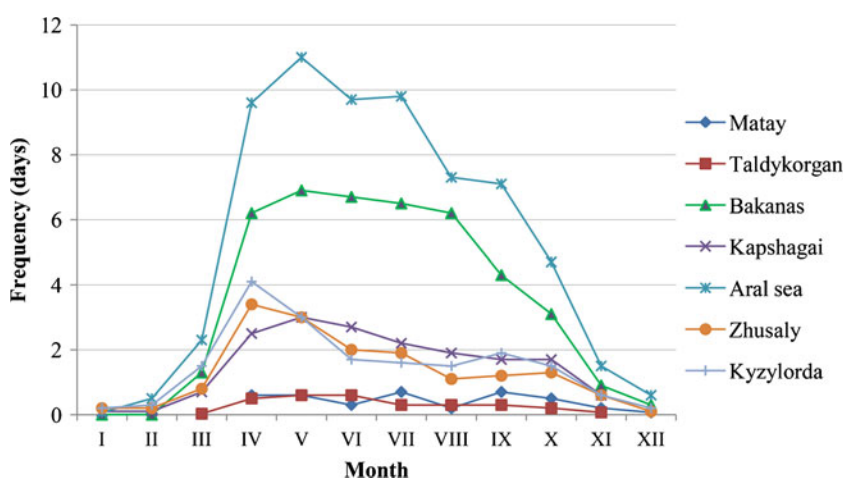

Fig. 3 Monthly average of dust/sand storm frequency for the period 1966–2003 in the southern desert zone of Kazakhstan

Table 1 Characteristics of the sands in the Southern Pre-Balkhash deserts (according to the data of Semenov 2011)

The coordinates of the selected sites		Characteristics of sampling location	Average size of sand particles, micron
latitude	longitude		
Saryesikatyrau sands			
45°58'	74°50'	Sand ridge in the takyr-like soil with Haloxylon	123
45°29'	75°12'	Ridge-hilly sands, semi-fixed sands, moving dunes nearby the Ayul 4 weather station	144
45°44'	75°09'	Ridge-hilly sands, height 10–12 m, dune sands	119
45°43'	75°07'	Ridge-hilly sands with deflated tops	105
45°46'	74°59'	Ridge-hilly sands are covered by bushes and undergo deflation	115
45°46'	74°57'	Deflated front ridge of Saryesikatyrau sands	125
45°20'	76°40'	Ridge-fixed sands in the southern part of Irizhar sands	148
45°55'	76°10'	Dune sands in the central part of Saryesikatyrau	128
Moiynkum sands			
44°45'	77°30'	Hillocky sands	129
Bestas sands			
46°13'	77°15'	Hillocky-ridge, hillocky with deflation hollows of semi-fixed sands in the northeast Bestas Desert	110
46°20'	77°14'	Ridge semi-fixed sands by height of 15–20 m	113
46°15'	77°15'	Ridge-hillocky sands	117
Zhamankum sands			
45°14'	77°52'	Hilly-ridge-gentle sands	129
45° 30'	77°38'	Ridge-hilly sands by height of 5–6 m	130
45°35'	77°34'	Sand ridges, semi-fixed sands	110
45°48'	77°10'	The moving dune by height of 8–9 m	104
46°03'	77°10'	Sand dunes, moving sands	100
45°34'	77°34'	Moving sands by height of 1.5 m	160
Zhalkum sands			
45°35'	78°34'	Gently undulating fixed sand	81
45°40'	78°37'	Non-fixed sand dunes with surrounded hilly fixed sands with bush	103
45°47'	78°40'	Moving sands along the road	113
Taukum sands			
44°17'	75°57'	The moving dune at the sand edge	126
44°19'	75°39'	Sand dunes, moving sands	150
44°30'	75°45'	Moving sands	113
44°20'	75°33'	Gently undulating weakly fixed sands at the edge of sand massif	150
44°47'	74°28'	Deflated dune	108
44°50'	74°34'	The moving dune by height of 12 m	123
44°36'	76°24'	Ridge-hilly fixed sands.	160

are more affected by human activity (Skotselias 1995). However, the number of sand/dust storms in the region was decreasing.

The number of days with deflation processes (dust/sand storms) reaches 30–90 days in the Moiynkum and Taukum deserts, in the Ili river deltas and valley, and on the southern coast of Balkhash Lake, decreasing up to 10–20 days in Saryesikatyrau desert, in the foothills of Zhetysu (Zhungar) Alatau. The most frequent storms were observed in the northern Aral Sea region, where their long-term average frequency reached 36–84 days per year, from 9 to 23 days every year in the eastern Aral Sea region. The largest dust/sand storm source area is the Pre-Aral Karakum and Kyzylkum deserts, where dust storms occur from 40 to 110 days per year (Semenov 2011). More often, they happen in summer; then a wind speed reaches 10–14 m/s (Babaev 1999). However, the significant decreasing trend is most obvious over the Karakum Desert in Turkmenistan where dust/sand storm occurrences declined from an average of 30 days per year to less than 20 days per year. In general, during the last decades, dust/sand storm frequency in the Central Asian deserts decreased, and considerable changes in the active source areas (Indoitu et al. 2012). The Aralkum Desert remains the dominant active source of aeolian sand/dust/salt aerosols in Central Asia and Kazakhstan.

Strong winds causes dust/sand storms in the Saryesikatyrau, Moiynkum, and Taukum deserts. When the wind force reaches the threshold value, the sand and dust particles are transported from the surface and start to move. Sand deflation in the region starts when winds cross the threshold of 6 m/s speed (Fediushina 1972a, b; Bagnold 1937). In the southern Pre-Balkhash deserts, the windy dry weather with wind speed of 6 m/s is observed from 60 to 127 days per year. In most areas of Taukum and Saryesikatyrau sands, such weather is 80–100 days per year; in the southern shore of Balkhash Lake, it reaches up to 100–120 days per year (Fediushina 1972a, b).

The seasonal distribution of dust/sand storms

Kazakhstan is a large region in variability of geographical and climatic features, therefore dust/sand storms activities vary with annual and inter-annual scales. In general, the Kazakhstan dust/sand storms outbreaks are common in the spring and summer seasons. According to the average number of days with dust/sand storms in different months for the period of 1966–2003, we found two peaks as follows: April–June and July–September (less in October) (Fig. 3). Due to the drastic rise in the temperatures and high wind speed in the spring, the southern deserts surfaces suffer from rapid evaporation of precipitation, which together with strong winds favors the development of dust/sand events. The southern Pre-Balkhash deserts (Bakanas weather station), Kyzylkum, Pre-Aral Karakum, and Aralkum (Aral Sea weather station) are the main regions of Kazakhstan, where dust/sand storms are common, especially during April through August and April–September (Fig. 3).

Average size of sand particles in the southern Pre-Balkhash deserts

The sand texture is an important feature which determines sand disposition to wind erosion. Average size of sand grains plays one of the main roles in the sand/dust transport. The sand grains in the southern Pre-Balkhash deserts have different size (Table 1). Most sands of this region have hilly-ridge relief and they undergo deflation process; their top and middle parts of the slopes weather (Semenov 2011). Large massifs of moving sands are located in the right bank of Aksu River near the Matay weather station, where these sands occupy an area of about 15–20 km^2. Moving sands are found also along the right bank of Karatal and Ili rivers. Average size of sand particles in the weather stations are as follows: Auyl 4, Kapshagai—130 μm; Kuigan, Shyganak—110 μm; and Bakanas, Matay—100 μm (Table 2). According to investigations of the grain size, the sands in our study area belong to the easily deflated type because their mean size is more than 100 μm in most areas (Skotselias 1995).

Sand/dust amount transport in the region and dominant direction of winds

Wind is a relief forming factor in a sandy desert. It causes deflation process, transfer, and accumulation of sand. Wind can erode and transport large quantities of fine particles and deposit them elsewhere on the surface. Average long-term annual amount of sand transportation in the southern Pre-Balkhash desert region reaches 66–2,940 t km^{-1} year^{-1} (Table 2). The removed particles will be transported to another region where they may form sand dunes on a beach or in a desert. High amount of sand transportation is observed in the eastern part of the southern Pre-Balkhash deserts (Matay Station), in the western coastal sands of the Lake (Kuigan Station), Moiynkum and Taukum sandy massifs, and small part of Saryesikatyrau (right bank of Ili river, Bakanas, and Kapshagai stations). A large part of the Saryesikatyrau desert has smaller average long-term annual transportation of sands (250–450 t km^{-1} year^{-1}). Therefore, the intensity of deflation processes in most parts of the Saryesikatyrau sands is much lower, and the ecological influence to the surrounding areas is low (Fig. 1).

Winds in the deserts—a constant phenomenon and the wind regime connected with a baric relief and synoptic conditions. Direction and rate of transfer are dependent on the wind regime in a particular desert territory (Babaev 1999).

The western winds are dominant in the southern Pre-Balkhash deserts and defined by the general circulation of air masses in the southeastern Kazakhstan (Skotselias 1995; Semenov 2011). As a consequence, the sand movement direction occurs in the east, southeast, and northeast (Auyl 4, Kuigan, Shyganak, and Matay stations). In the southern parts of the region, the relief and local orographic conditions

Table 2 Main characteristics of sand amount transport by wind in the southern Pre-Balkhash deserts

Weather stations	Average size of sand particles, micron	Sand amount transport (M) t km^{-1} year^{-1}
Matay	100	2,634.5
Naimansuiek	100	65.9
Auyl 4	130	246.6
Kuigan	110	2,936.1
Bakanas	100	2,267.2
Shyganak	110	291.9
Kapshagai	130	2,594.5

provoke appearance of strong winds. The underlying relief influences the speed and direction of active dunes' movement (Yang et al. 2007). Therefore, at the Kapshagay station, a wind of west direction is observed; it is a maximum wind vector of west direction in the southern Pre-Balkhash desert. This is due to a well-known local easterly Shelek wind. Apart from the winds caused by a general circulation in the atmosphere, there are local winds in various parts of a desert. Local winds, often strong and steadily blowing, are witnessed in the vicinity of mountain spurs and narrows (Babaev 1999). The Shelek is a mountain and valley wind which is formed by the movement of cold air from the area of the glacier (Ile Alatau) at the source of the Shelek river to Ili river valley. The wind speed during the year is 8–10 m/s (Murzaev 1958). The nature of the manifestation of mountain–valley winds depends on the height of the ridges, slope exposure, and directivity of gorges. Depending on this, the wind direction might or might not coincide with the general pattern of winds of the surrounding plains, i.e., intensify or attenuate. Additionally, local air circulation in the region is dominant than general circulation in the atmosphere (Sidorov 2006; Uteshev and Semenov 1967). The wind vectors in Bakanas, Kapshagai, and Naimansuiek are directed along the river valleys (Fig. 1).

Conclusions

Human activities have changed the levels of Balkhash Lake and Ili river regulation, provoke land/soil degradation, and contributed to the development of intensive deflation and desertification processes.

The study of sandy deserts in the southern Pre-Balkhash region allows qualitative assessment of the modern deflation processes intensity in this area. The sands of our study region are most affected by the deflation processes. Large areas of sands are observed mainly on floodplains and in the coastal zone of Balkhash Lake. According to the constructed map, it is possible to do the quantitative assessment of the sands transferred by the wind. Average long-term amount of sand transportation varies from 66 to 2,940 t km^{-1} $year^{-1}$.

The dust/sand storms are typical for the southern Pre-Balkhash deserts with sparse vegetation cover and availability of easy wind-blown sand particles on the surface. The Taukum, Moiynkum deserts, Ili river deltas and valleys, and southern coastal of the lake are most prone to dust/sand storms. This area is the main source of aerosols, which move with wind flow and have great affect on the climate and environmental situation in the southeastern Kazakhstan. These aerosols can seriously pollute the air and water and lead to the soil salinization and vegetation degradation.

Sand/dust movement directions of the region allow predicting the possibility of moving sands in the southern Pre-Balkhash region.

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